CLAIMS

1. A method for removing an electrically conductive material from a microelectronic substrate, comprising:

positioning a first conductive electrode proximate to the microelectronic substrate;

positioning a second conductive electrode proximate to the microelectronic substrate and spaced apart from the first conductive electrode; and

removing the conductive material from the microelectronic substrate by passing a varying current through the first and second electrodes while the first and second electrodes are spaced apart from the conductive material of the microelectronic substrate.

2. The method of claim 1, further comprising:

engaging the microelectronic substrate with a planarizing medium while the microelectronic substrate is positioned proximate to the electrodes; and

moving at least one of the microelectronic substrate and the planarizing medium relative to the other to remove material from the microelectronic substrate by a chemical and/or chemical-mechanical process.

3. The method of claim 1 wherein the microelectronic substrate has a surface facing toward the first and second electrodes, further comprising:

selecting the first and second electrodes to have a combined surface area facing toward the surface of the microelectronic substrate that is less than the area of the surface of the microelectronic substrate; and

moving at least one of the microelectronic substrates and the electrodes relative to the other while applying an electrical current to the at least one electrode.

4. The method of claim 1, further comprising disposing a liquid and/or gel electrolyte between the electrodes and the microelectronic substrate.

5. The method of claim 1, further comprising disposing a dielectric layer between the microelectronic substrate and the first electrode.

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6. The method of claim 1, further comprising varying an amplitude and/or polarity of the current at a first frequency and superimposing on the first frequency an amplitude variation having a second frequency less than the first frequency.

7. The method of claim 1 wherein the microelectronic substrate has a planform shape, further comprising selecting the first electrode to have a planform shape generally similar to a first portion of the planform shape of the microelectronic substrate and selecting the second electrode to have a planform shape generally similar to a second portion of the planform shape of the microelectronic substrate.

8. The method of claim 1 wherein the first and second electrodes define an electrode pair and the conductive material is a first portion of conductive material, and wherein the method further comprises:

positioning a second electrode pair proximate to the microelectronic substrate; and

applying a varying current to the second electrode pair to remove a second portion of conductive material from the microelectronic substrate.

9. The method of claim 1 wherein applying a varying current includes applying at least one of a single phase and a multi-phase alternating current to at least one of the first and second electrodes.

10. The method of claim 1 wherein the microelectronic substrate has a surface facing toward the first and second electrodes, further comprising selecting the first and second electrodes to have a combined surface area facing toward the surface of the microelectronic substrate that is approximately equal to the surface of the microelectronic substrate.

11. The method of claim 1, further comprising controlling a rate at which the conductive material is removed from the microelectronic substrate by controlling a distance between at least one of the electrodes and the microelectronic substrate.

12. The method of claim 1, further comprising controlling a rate at which the conductive material is removed from the microelectronic substrate by spacing a first portion of the first electrode a first distance away from a first region of the microelectronic substrate and spacing a second portion of the first electrode a second distance away from a second region of the electrode with the first distance being different than the second distance.

13. The method of claim 1, further comprising engaging the microelectronic substrate with a planarizing medium and moving at least one of the microelectronic substrate and the planarizing medium relative to the other after applying an electrical current to the electrodes and without removing the microelectronic substrate from a region proximate to the electrodes.

14. The method of claim 1 wherein removing the conductive material by applying a varying current includes roughening a surface of the conductive material to form a roughened region, further comprising smoothing the roughened region by engaging the microelectronic substrate with a planarizing medium adjacent to the electrodes and moving at least one of the microelectronic substrate and the planarizing medium relative to the other.

15. The method of claim 1, further comprising:

at least partially immersing the microelectronic substrate in a liquid electrolyte;

moving portions of the electrically conductive material from the microelectronic substrate to the liquid electrolyte; and

removing the portions from the liquid electrolyte.

16. The method of claim 1, further comprising selecting the electrically conductive material to include tungsten, tantalum, gold, copper and/or platinum.

17. The method of claim 1, further comprising selecting an electrolyte adjacent to the microelectronic substrate to include hydrochloric acid.

18. The method of claim 1, further comprising selecting a dielectric material between the microelectronic substrate and the electrodes to include Teflon™.

19. The method of claim 1, further comprising:

disposing a first quantity of an electrolyte between the conductive material and the electrodes only in a first region of the microelectronic substrate immediately proximate to the electrodes;

moving the microelectronic substrate and/or the electrodes to align a second region of the microelectronic substrate with the electrodes; and

disposing a second quantity of the electrolyte between the conductive material and the electrodes only in the second region of the microelectronic substrate.

20. The method of claim 1, further comprising:

disposing a first electrolyte adjacent to the first electrode;

disposing a second electrolyte different than the first electrolyte adjacent to the conductive material of the microelectronic substrate; and

at least restricting movement of the second electrolyte toward the first electrode.

21. The method of claim 1, further comprising:

generating a signal corresponding to a rate at which the conductive material is removed from the microelectronic substrate and/or an amount of conductive material remaining on the microelectronic substrate; and

controlling an interaction between the microelectronic substrate and the electrodes based on the input signal.

22. The method of claim 1, further comprising at least restricting contact between the first electrode and a liquid adjacent to the first conductive material of the

microelectronic substrate by disposing a dielectric film between the first electrode and the liquid.

23. A method for removing an electrically conductive material from a microelectronic substrate, comprising:

positioning a first conductive electrode proximate to the microelectronic substrate;

positioning a second conductive electrode proximate to the microelectronic substrate and spaced apart from the first conductive electrode; and

removing the conductive material from the microelectronic substrate by passing a varying current through the first and second electrodes without contacting the first and second electrodes directly with the conductive material of the microelectronic substrate.

24. The method of claim 23, further comprising varying an amplitude and/or polarity of the current at a first frequency and superimposing on the first frequency an amplitude variation having a second frequency less than the first frequency.

25. The method of claim 23 wherein the first and second electrodes define an electrode pair and the conductive material is a first portion of conductive material, and wherein the method further comprises:

positioning a second electrode pair proximate to the microelectronic substrate; and

applying a varying current to the second electrode pair to remove a second portion of conductive material from the microelectronic substrate.

26. The method of claim 23, further comprising:

engaging the microelectronic substrate with a planarizing medium while the microelectronic substrate is positioned proximate to the electrodes; and

moving at least one of the microelectronic substrate and the planarizing medium relative to the other.

27. The method of claim 23, further comprising:

disposing a first quantity of an electrolyte between the conductive material and the electrodes only in a first region of the microelectronic substrate immediately proximate to the electrodes;

moving the microelectronic substrate and/or the electrodes to align a second region of the microelectronic substrate with the electrodes; and

disposing a second quantity of the electrolyte between the conductive material and the electrodes only in the second region of the microelectronic substrate.

28. The method of claim 23, further comprising:

disposing a first electrolyte adjacent to the first electrode;

disposing a second electrolyte different than the first electrolyte adjacent to the conductive material of the microelectronic substrate; and

at least restricting movement of the second electrolyte toward the first electrode.

29. A method for forming a planarizing medium, comprising:

forming a planarizing pad body having a planarizing surface to engage a surface of a microelectronic substrate;

disposing a first electrode at least adjacent to the planarizing pad body and spaced apart from the planarizing surface with the first electrode coupleable to a source of varying current;

disposing a second electrode at least adjacent to the planarizing pad body with the second electrode spaced apart from the first electrode; and

disposing a dielectric material between the first and second electrodes.

30. The method of claim 29, further comprising selecting the first electrode to include a carbonaceous material.

31. The method of claim 29, further comprising fixedly disposing a plurality of abrasive elements in the planarizing pad body at least proximate to the planarizing surface.

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32. The method of claim 29, further comprising disposing a film between the planarizing surface and the electrodes

33. A method for removing an electrically conductive material from a microelectronic substrate, comprising:

positioning a first conductive electrode proximate to the conductive material of the microelectronic substrate;

positioning a second conductive electrode proximate to the conductive material of the microelectronic substrate and spaced apart from the first conductive electrode;

disposing a first electrolyte adjacent to at least one of the first and second electrodes;

disposing a second electrolyte different than the first electrolyte adjacent to the conductive material of the microelectronic substrate;

at least restricting motion of the second electrolyte toward the one electrode; and

removing the conductive material from the microelectronic substrate by passing a varying current through the first and second electrodes while the first and second electrodes are spaced apart from the conductive material of the microelectronic substrate.

34. The method of claim 33 wherein at least restricting motion of the second electrolyte includes disposing a permeable membrane between the one electrode and the microelectronic substrate and passing the first electrolyte through the membrane.

35. The method of claim 33, further comprising selecting the first electrolyte to include sodium chloride, potassium chloride, and/or or copper sulfate.

36. The method of claim 33, further comprising selecting the second electrolyte to include hydrochloric acid.

16 ~~37~~. A method for removing an electrically conductive material from a microelectronic substrate, comprising:

positioning a first conductive electrode proximate to a first portion of the microelectronic substrate;

positioning a second conductive electrode proximate to the first portion of microelectronic substrate and spaced apart from the first conductive electrode, the first and second electrodes defining an electrode pair;

removing the conductive material from the first portion of the microelectronic substrate by passing a varying current through the first and second electrodes while the first and second electrodes are spaced apart from the conductive material of the microelectronic substrate;

moving at least one of the microelectronic substrate and the electrode pair relative to the other to align a second portion of the microelectronic substrate with the electrode pair; and

removing the conductive material from the second portion of the microelectronic substrate by applying a varying current to at least one of the first and second electrodes while the first and second electrodes are spaced apart from the conductive material of the microelectronic substrate.

11 ~~38~~. The method of claim 16 ~~37~~, further comprising:

directing a first flow of electrolyte only to the first portion of the microelectronic substrate when the electrode pair is proximate to the first potion; and

directing a second flow of electrolyte only to the second portion of the microelectronic substrate when the electrode pair is proximate to the second potion.

39. A method for removing an electrically conductive material from a microelectronic substrate, comprising:

engaging a surface of the microelectronic substrate with a planarizing medium; and

removing at least a portion of the electrically conductive material from the microelectronic substrate by passing a varying electrical current through the microelectronic

substrate while engaging the surface of the microelectronic substrate with the planarizing medium.

40. The method of claim 39, further comprising moving at least one of the microelectronic substrate and the planarizing medium relative to the other.

41. The method of claim 39, further comprising:

spacing a first electrode and a second electrode apart from the microelectronic substrate and apart from each other; and

coupling at least one of the electrodes to a source of varying current to pass the current from the one electrode, through an electrolyte adjacent to the microelectronic substrate and to the other electrode.

42. The method of claim 39 wherein removing the conductive material by applying a varying current includes roughening a surface of the conductive material to form a roughened region, further comprising smoothing the roughened region by moving at least one of the microelectronic substrate and the planarizing medium relative to the other.

12 ~~43.~~ A method for removing an electrically conductive material from a microelectronic substrate, comprising:

positioning a first conductive electrode at least proximate to a first portion of the microelectronic substrate;

positioning a second conductive electrode at least proximate to the first portion of the microelectronic substrate and spaced apart from the first conductive electrode, the first and second electrodes defining a first electrode pair;

positioning a second electrode pair at least proximate to a second portion of the microelectronic substrate, the second electrode pair including a third electrode and a fourth electrode spaced apart from the third electrode; and

removing the conductive material from the microelectronic substrate by passing a first varying current through the first and second electrodes and passing a second varying current through the third and fourth electrodes.

13 ~~44~~. The method of claim 12 ~~43~~, further comprising spacing the first and second electrodes apart from the microelectronic substrate while applying the first varying current.

14 ~~45~~. The method of claim 12 ~~43~~, further comprising spacing the first electrode pair a first distance from a surface of the microelectronic substrate and spacing the second electrode pair a second distance from the surface of the microelectronic substrate with the first distance greater than the second distance.

15 ~~46~~. The method of claim 12 ~~43~~, further comprising:

spacing the first and second electrode pair apart from each other by a first distance;

spacing a third and fourth electrode pair apart from each other by a second distance greater than the first distance, with each of the third and fourth electrode pairs including two spaced apart electrodes;

aligning the third electrode pair with a third portion of the microelectronic substrate and aligning the fourth electrode pair with a fourth portion of the microelectronic substrate; and

removing the conductive material from the third and fourth portions of the microelectronic substrate by passing a third varying current through the third electrode pair and passing a fourth varying current through the fourth electrode pair.

16 ~~47~~. The method of claim 12 ~~43~~ wherein the first varying current is approximately identical to the second varying current.

17 ~~48~~. The method of claim 12 ~~43~~ wherein an amplitude of the first varying current is greater than an amplitude of the second varying current.

49. An apparatus for removing conductive material from a microelectronic substrate, comprising:

a support member having at least one engaging surface to support the microelectronic substrate;

a first electrode spaced apart from the support member and from the microelectronic substrate when the microelectronic substrate is supported by the support member; and

a second electrode spaced apart from the support member and from the microelectronic substrate when the microelectronic substrate is supported by the support member, the second electrode being spaced apart from the first electrode, at least one of the first and second electrodes being coupleable to a source of varying current.

50. The apparatus of claim 49 wherein the first and second electrodes define an electrode pair and at least one of the electrode pair and the support member is movable relative to the other while the at least one of the first and second electrodes is coupled to the source of varying current.

51. The apparatus of claim 49, further comprising an electrolyte vessel configured to support a liquid electrolyte, and further wherein the support member is positioned relative to the electrolyte vessel to support the microelectronic substrate within the vessel.

52. The apparatus of claim 49, further comprising a dielectric layer at least proximate to the first electrode, the dielectric layer being positioned between the microelectronic substrate and the first electrode when the microelectronic substrate is supported by the support member.

53. The apparatus of claim 49, further comprising the current source, the current source configured to vary an amplitude of the current at a first frequency, the current source including an amplitude modulator to superimpose on the first frequency an amplitude and/or polarity variation having a second frequency less than the first frequency.

54. The apparatus of claim 49 wherein the microelectronic substrate has a planform shape, the first electrode has a planform shape generally similar to a first portion of the planform shape of the microelectronic substrate and the second electrode has a planform

shape generally similar to a second portion of the planform shape of the microelectronic substrate.

55. The apparatus of claim 49 wherein the first and second electrodes define a first electrode pair, and wherein the apparatus further comprises:

a third electrode spaced apart from the support member and from the microelectronic substrate when the microelectronic substrate is supported by the support member; and

a fourth electrode spaced apart from the support member and from the microelectronic substrate when the microelectronic substrate is supported by the support member, the fourth electrode being spaced apart from the third electrode, at least one of the third and fourth electrodes being coupleable to a source of varying current.

56. The apparatus of claim 49, further comprising the current source, and further wherein the current source includes a single phase or a multi-phase alternating current supply.

57. The apparatus of claim 49 wherein the microelectronic substrate has a surface facing toward the first and second electrodes, and further wherein the first and second electrodes have a combined surface area facing toward the surface of the microelectronic substrate that is approximately equal to the surface area of the microelectronic substrate.

58. The apparatus of claim 49 wherein the microelectronic substrate has a surface facing toward the first and second electrodes, and further wherein the first and second electrodes have a combined surface area facing toward the surface of the microelectronic substrate that is less than the area of the surface of the microelectronic substrate, at least one of the microelectronic substrate and the electrodes being moveable relative to the other while an electrical current is applied to the at least one electrode.

59. The apparatus of claim 49 wherein the first and second electrodes define an electrode pair, further wherein at least one of the electrode pair and the support member is

moveable toward and away from the other to control a distance between the electrode pair and the microelectronic substrate when the microelectronic substrate is supported by the support member.

60. The apparatus of claim 49 wherein at least one of the first electrode and the support member is movable relative to the other and the first electrode includes a first surface portion and a second surface portion, the first and second surface portions facing the microelectronic substrate when the microelectronic substrate is supported by the support member, the first portion being positioned further from the microelectronic substrate than the second portion when a first region of the microelectronic substrate opposite the first portion has a slower velocity relative to the first electrode than does a second region of the microelectronic substrate opposite the second portion of the first electrode.

61. The apparatus of claim 49, further comprising a planarizing medium positioned proximate to the support member to engage the support member when the support member engages the microelectronic substrate.

62. The apparatus of claim 49, further comprising a liquid or gel electrolyte adjacent to the first electrode.

63. The apparatus of claim 49, further comprising a conduit coupleable to a source of electrolyte, the conduit having an outlet aperture proximate to the first and second electrodes.

64. The apparatus of claim 49, further comprising a sensor positioned at least proximate to the support member to detect a rate at which the conductive material is removed from the microelectronic substrate and/or an amount of conductive material remaining on the microelectronic substrate.

65. The apparatus of claim 49, further comprising:

the current source coupled to the at least one electrode; and

a sensor positioned at least proximate to the support member to detect a rate at which the conductive material is removed from the microelectronic substrate and/or an amount of conductive material remaining on the microelectronic substrate, the sensor being coupled to the current source and/or at least one of the electrodes to control an electrical potential imparted to the microelectronic substrate when the microelectronic substrate is supported by the support member.

66. An apparatus for removing a conductive material from a microelectronic substrate, comprising:

a carrier having at least one engaging surface to support a microelectronic substrate;

a polishing pad proximate to the carrier and having a polishing surface to engage the microelectronic substrate, at least one of the polishing pad and the carrier being movable relative to the other;

a first electrode proximate to the polishing surface; and

a second electrode proximate to the polishing surface and spaced apart from the first electrode, at least one of the first and second electrodes being coupleable to a source of varying electrical current.

67. The apparatus of claim 66 wherein the first and second electrodes define an electrode pair and at least one of the electrode pair and the carrier is movable relative to the other while the at least one of the first and second electrodes is coupled to the source of varying current.

68. The apparatus of claim 66, further comprising the current source, further wherein the current source is configured to vary an amplitude of the current at a first frequency, still further wherein the current source includes an amplitude modulator to superimpose on the first frequency an amplitude and/or polarity variation having a second frequency less than the first frequency.

69. The apparatus of claim 66 wherein the first and second electrodes define a first electrode pair, and wherein the apparatus further comprises:

a third electrode spaced apart from the carrier and from the microelectronic substrate when the microelectronic substrate is supported by the carrier; and

a fourth electrode spaced apart from the carrier and from the microelectronic substrate when the microelectronic substrate is supported by the carrier, the fourth electrode being spaced apart from the third electrode, at least one of the third and fourth electrodes being coupleable to a source of varying current.

70. The method of claim 66, further comprising:

the current source coupled to the at least one electrode; and

a sensor positioned at least proximate to the support member to detect a rate at which the conductive material is removed from the microelectronic substrate and/or an amount of conductive material remaining on the microelectronic substrate, the sensor being coupled to the current source and/or at least one of the electrodes to control an electrical potential imparted to the microelectronic substrate when the microelectronic substrate is supported by the carrier.

71. An apparatus for removing an electrically conductive material from a microelectronic substrate, comprising:

a support member having an engaging surface to support the microelectronic substrate;

a first conductive electrode spaced apart from the support member and spaced apart from the microelectronic substrate when the microelectronic substrate is supported by the support member;

a second conductive electrode spaced apart from the support member and the first conductive electrode, at least one of the first and second electrodes being coupleable to a source of varying current; and

an electrolyte flow restrictor positioned between the support member and at least one of the conductive electrodes to at least restrict a flow of an electrolyte toward at least one of the first and second electrodes.

72. The apparatus of claim 71, further comprising:

a first electrolyte adjacent to the microelectronic substrate and selected from sodium chloride, potassium chloride and copper sulfate; and

a second electrolyte adjacent to at least one of the electrodes and selected to include hydrochloric acid.

73. ~~The apparatus of claim 71~~ wherein the flow restrictor includes a permeable membrane.

74. An apparatus for removing an electrically conductive material from a microelectronic substrate, comprising:

a support member having at least one engaging surface to support the microelectronic substrate;

first and second conductive electrodes spaced apart from each other, spaced apart from the support member, and spaced apart from the microelectronic substrate when the microelectronic substrate is supported by the support member, at least one of the first and second electrodes being coupleable to a source of varying current, the first and second electrodes defining an electrode pair, at least one of the support member and the electrode pair being movable relative to the other while the varying current is applied to the at least one of the first an second electrodes.

75. The apparatus of claim 74, further comprising a conduit coupleable to a source of electrolyte and having an aperture positioned proximate to at least one of the electrodes.

24 ~~76~~. An apparatus for removing an electrically conductive material from a microelectronic substrate, comprising:

a support member having at least one engaging surface to support the microelectronic substrate;

first and second conductive electrodes spaced apart from each other and defining a first electrode pair, the first electrode pair being at least proximate to the

microelectronic substrate when the microelectronic substrate is supported by the support member, at least one of the first and second electrodes being coupleable to a source of varying current; and

third and fourth conductive electrodes spaced apart from each other and defining a second electrode pair spaced apart from the first electrode pair, the second electrode pair being at least proximate to the microelectronic substrate when the microelectronic substrate is supported by the support member, at least one of the third and fourth electrodes being coupleable to a source of varying current.

25 ~~77~~. The apparatus of claim 24 ~~76~~ wherein the first and second electrodes are positioned to be spaced apart from the microelectronic substrate when the microelectronic substrate is supported by the support member.

26 ~~78~~. The apparatus of claim 24 ~~76~~ wherein the first electrode pair is positioned a first distance from a surface of the microelectronic substrate and the second electrode pair is positioned a second distance from the surface of the microelectronic substrate when the support member supports the microelectronic substrate, with the first distance greater than the second distance.

27 ~~79~~. The apparatus of claim 24 ~~76~~, further comprising a third and fourth electrode pair, the third and fourth electrode pairs each including two spaced apart electrodes, the first and second electrode pair spaced apart from each other by a first distance and the third and fourth electrode pair spaced apart from each other by a second distance greater than the first distance.

28 ~~80~~. The apparatus of claim 24 ~~76~~ wherein an amplitude of varying current supplied to the first and second electrodes is different than an amplitude of varying current supplied to the third and fourth electrodes.

29 ~~81~~. The apparatus of claim 24 ~~76~~ wherein a frequency of varying current supplied to the first and second electrodes is higher than a frequency of varying current supplied to the third and fourth electrodes.